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(54) Method of deep soil compacting from a surface

(57) A method of a deep soil compacting from a surface by means of seismic dynamic compacting - referred to as seismic-compaction - with a use of sequences of seismic-vibrations of high power and variable parameters of vibrations, wherein an energy of a single stroke impulse on the soil surface is replaced by a superposition of corresponding number of cycles of lower-energetic, controlled sequences of vibrations of seismic frequencies within a range from several to several dozens of hertz, sent to a stiff plate of any shape and size contacted with a subsoil, onto which a static force of a preload load caused by a heavy weight M1 is applied, and simultaneously a dynamic load forced by a periodic force Fw of defined parameters of vibration frequencies, amplitude and emission time is applied, and of a force directed always downward, also for accelerations of forcing greater then 1g.

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Description

[0001] The object of the invention is a method of deep soil compacting from a surface by means of seismic dynamic compacting with a use of sequences of seismic vibrations of high power and of variable parameters of vibrations depending on susceptibility of a medium to settlement, and on limitations resulting from work safety, the vibrations being sent at one vibration position by a statically loaded and vibrating stiff plate onto the soil surface.

[0002] The method of dynamic soil compacting from a surface known heretofore was implemented by a shallow vibratory compacting with a rolling, vibratory roll or a plate vibrator.

[0003] Unfortunately, the method was efficient only up to a depth of about 1.5 meter and to compacting of embankments by overlaying thin layers to a depth of several dozen centimeters.

[0004] The method was commonly used at road-making and embankment-making by compacting of building base from thin layers of about 0.5 meters in depth. Similarly, a shallow and less energy-consuming method is implemented by providing low-power vibrations by light vibrating monochromatic plate vibrators used for compacting of subsoil for walkways, floors and other light constructions.

[0005] These methods are not efficient when a deep compacting from a surface, of high, operated structures on embankments or their subsoil has to be made without disassembly of the structures.

[0006] Disassembly of the structures often results in closure of the object and in high costs of repair work.

[0007] An other known method consists in a deep, impact compacting with a use of stroke caused by falling a heavy weight from a high height.

[0008] The impact method is commonly used for a deep, point-wise acting i.e. crater-like, dynamic soil compacting from a surface utilizing an energy of heavy weight falling from a high level. The method is characterized by a high non-homogeneity of compacting and loosening at the surface caused by wedges of uplift pressure and exceeding of medium elasticity. Moreover, about 70% of energy of impulse of the stroke creates strong surface waves having elliptical nature of vibrations that are dangerous for buildings on embankments and for existing infrastructure. Because of strong, shearing horizontal stresses, the waves loosen the already compacted zone within a radius of several dozens up to several hundreds meters, depending on the stroke energy. The method is not suitable for uniform compacting of soil and buildings on embankments, where high homogeneity of spatial compaction is required. Furthermore, the method is dangerous in case of moving and manipulating with a machinery having high extension arm, hanging heavy weight, on high, linear structures on embankments.

[0009] The aim of the present invention is to develop an efficient method of a deep, dynamic, homogeneous (both in terms of surface and space) soil compacting from a surface, without necessity of uncovering deeper layers or disassembling structure on embankments, safe for surrounding infrastructure and in terms of work safety.

[0010] The objective has been achieved by a use of a method of a deep soil compacting from a surface using seismic dynamic compacting referred to as seismo-compaction with a use of sequences of seismo-vibrations of high power and variable parameters of vibrations depending on susceptibility of a medium to settlement, and on limitations to account for work safety. According to the invention, an energy of a single stroke impulse on the soil surface is replaced by a superposition of corresponding number of cycles of low-energetic, controlled sequences of vibrations of seismic frequencies within a range from several to several dozens of hertz, sent to a stiff plate of any shape and size contacted with a subsoil, onto which a static force of a preload load caused by a heavy weight M1 is applied, and simultaneously a dynamic load forced by a periodic force FW of defined parameters of vibration frequencies, amplitude and emission time is applied, particularly of a maximum value lower than static load Mlxg in order to maintain a permanent contact of the plate with the subsoil, and of a force direction directed always downward, also for accelerations of forcing greater then 1g, which provides cumulating of deformations under the plate and achieving fast effect of compacting and consolidation from subsequent cycles of vibrations on a given point of vibration, irrespective of a technical system to implement the way from a point to another point.

[0011] The commonly known phenomenon that accompanies earthquakes is a considerable, sometimes up to several meters, ground settlement relevant to a compacting of a medium caused by a sequences of seismic vibrations (lasting several seconds) at the near-surface zone.

[0012] In that case, a generated seismic wave is a seismic moment, at the high depth, at the epicenter and propagates radial in the earth direction at the frequency of several hertz.

[0013] In the method according to the disclosed invention, a controlled, artificial and safe, superficial source of induction of continuous seismic vibrations of suitable energetic parameters, able to soil compacting and consolidation at the near-surface zone, at any depth in the sense of engineering issues, is applied. The method is based on two physical phenomena occurring in grounds:

- the first phenomenon being a soil compacting and consolidation by application of a constant, of a suitable value, preliminary, static pressure on a plate, the phenomenon lasting many days and even years.
- the second phenomenon being a compacting and

dynamic consolidation by means of application onto a preliminary , statically loaded plate, of forced sequences of dynamic periodic strokes having suitable vibration characteristic and a suitable time of phenomenon duration (an instant, minutes or hours). Even in case of acceleration of the plate greater than 1g, the dynamic force is always directed downward as long as it is lower than a static load.

[0014] Unlike the static load, a dynamic periodic impulse force causes during each cycle, a rearrangement of soil particles and their considerable packing, especially in loose media, which results in their fast settlement and compaction. In a compact medium, a process of fast dynamic displacement of water present in a ground and a fast consolidation occurs.

[0015] In general, a scale of settlement depends on an initial soil density, a depth of a strata to be consolidated and on a maximum shape deformation of the soil.

[0016] Even sands of relative density > 75%, which in normal cases do not exhibit any considerable settlement, can be dynamically compacted from 1 to 2% of depth of the strata. On the other hand, compaction of a loose sand due to dynamic loads is the most often a cause of differential ground settlement.

[0017] Thus, the effect of dynamic soil compacting under the plate can last a moment or not more than hours, and not days or years, as it is in the case of static, natural consolidation of a subsoil beneath the founded objects.

[0018] Dynamic compacting can be inefficient, when a sum of static and dynamic loading is lower than a half of carrying strength of soil. Thus the important question is a proper evaluation of susceptibility of soil to dynamic loads.

[0019] Amount of vibration cycles necessary to receive desired compaction depends on strength to dynamic deformation Re=dN/de, where N is a number of cycles, and e is a deformation, i.e. cumulated settlement. From laboratory testing it results that, in general, level of settlement is in direct proportion to a depth of strata H of a layer to be consolidated and to natural logarithm of a number of vibration cycles N, and is inversely proportional to strength to dynamic deformation r(ε). Upon field dynamic tests and study of subsoil susceptibility, corresponding parameters of dynamic force in a range of many-second sequences of seismic frequencies from 5 to 100 Hz, having linear or other rate of changes, are designed according to the invention. This can also include composing of mono-frequency sequences from that range, with or without the use of resonance frequencies of a vibrator-subsoil system.

[0020] Hereafter, a detailed description of the method of deep, seismic soil compacting from surface, with a use of high-power seismic vibration sequences, and vibrations dependent on limitations resulting from work safety and on susceptibility of the soil to settlement, consisting in that a high energy of a single stroke impulse onto the soil surface, e.g. of a falling weight, is replaced by a superposition of respective number of cycles of lower-energy, controlled sequences of seismic-vibrations having seismic frequencies within a range from several to several dozens hertz, sent to a stiff plate of any shape and size contacted with a subsoil, onto which a static force of a preload load caused by a heavy weight M1 is applied, and simultaneously a dynamic load forced by a periodic force Fw of defined parameters of vibration frequencies, amplitude and emission time is applied, particularly of a maximum value lower than static load M1 x g in order to maintain a permanent contact of the plate with the subsoil, and of a force directed always downward, also for accelerations of forcing greater then 1g, which provides cumulating of deformations under the plate and achieving a fast effect of compacting and consolidation from subsequent cycles of vibrations on a given point of vibration.

[0021] An important economic advantage of a method according to the invention is also that it does not require expensive investment to build suitable source of vibrations, but it can be effectively implemented using an existing heavy seismic servo-hydraulic or electromagnetic vibrator.

[0022] That machinery is commonly used as a source of induction of seismic vibrations for geological and exploration work. In general, the servo-hydraulic system is composed of an external mass of a static load of a plate of a weight 20 ton and more, a vibrating system consisting of a reaction mass of 1 to 3 ton, coupled with a stiff plate (hydraulic coupling through a piston rod). The whole system of high-pressure hydraulics is operated electronically and a through low-pressure hydraulic system.

[0023] This makes it possible to adjust optimal vibration parameters flexibly depending on a subsoil susceptibility and to limit force and velocity of vibration displacement, where it is necessary, and the energy is compensated by a duration time and number of vibrations, to achieve cumulated settlement, (thus, to achieve the desired compacting degree).

[0024] In case of exceeding of bearing capacity of the soil, a distinct settlement of a soil under the plate will occur. After n vibration sequences at a given point and when settlement of the soil under the plate is stabilized, we determine an optimum number and distribution of vibration cycles over time, that are necessary to reach the desired degree of compacting of the soil characterized by local susceptibility to settlement.

[0025] Upon determination of optimum parameters of dynamic force, i.e. amplitude of vibration frequencies and their duration time, the routine vibrations are carried out from one point to another, with a continuous or pointwise coverage of surface, depending on a design and a range of work.

[0026] To summarize, such a system of vibrations in a field close to vibration source, at a depth lower than a length of generated wave, generates the highest soil stresses and displacement, which further are propagat-

ed into the medium up to several kilometers in a form of seismic compression wave. Thus, the vibration energy is effectively transferred far behind a zone of direct interaction of a plate on a subsoil, and can be - on the way -at any place, utilized, especially to compact soil at a near-surface zone. The more loose the soil is, the greater energy is used to compact the soil, and the lower energy is used for transport.

Claims

1. A method of a deep soil compacting from a surface by means of seismic dynamic compacting - referred to as seismic-compaction - with a use of sequences of seismic-vibrations of high power and variable parameters of vibrations depending on susceptibility of a medium to settlement, and on limitations resulting from work safety, **characterized in that** an energy of a single stroke impulse on the soil surface is replaced by a superposition of corresponding number of cycles of lower-energetic, controlled sequences of vibrations of seismic frequencies within a range from several to several dozens of hertz, sent to a stiff plate of any shape and size contacted with a subsoil, onto which a static force of a preload load caused by a heavy weight M1 is applied, and simultaneously a dynamic load forced by a periodic force Fw of defined parameters of vibration frequencies, amplitude and emission time, is applied, particularly of a maximum value lower than static load Mlxg in order to maintain a permanent contact of the plate with the subsoil, and of a force directed always downward, also for accelerations of forcing greater then 1g, which provides cumulating of deformations under the plate and achieving fast effect of compacting and consolidation from subsequent cycles of vibrations at a given point of vibration, irrespective of a technical system to implement the method from one point to another.